Copy No. _____

Defence Research and Development Canada | Recherche et développement pour la défense Canada

DEFENCE R&D DÉFENSE

Reverberation Inversion Enhancements Using BASE 04 Data

C. Calnan
xwave

xwave
36 Solutions Drive
Halifax, NS B3S 1N2

Project Manager: C. Calnan, 902-495-2000

Contract Number: W7707-05-2983

Contract Scientific Authority: J. Theriault, 902-426-3100 ext 376

xwave Contract Number: 1009997

Defence R&D Canada – Atlantic

Contract Report
DRDC Atlantic CR 2006-046
October 2006

Canada

This page intentionally left blank.

Reverberation Inversion Enhancements Using BASE 04 Data

C. Calnan
xwave

xwave
36 Solutions Drive
Halifax, N.S.
B3S 1N2

Project Manager: C. Calnan, 495-2000

Contract Number: W7707-05-2983

Contract Scientific Authority: J. Theriault 902-426-3100 Ext 376

xwave Contract Number: 1009997

Defence R&D Canada – Atlantic

Contract Report
DRDC Atlantic CR 2006-046
October 2006

Colin Calnan

C. Calnan

Approved by

J. Theriault

Contract Scientific Authority

Approved for release by

K. Foster

A/ Chair, Document Review Panel (DRP)

Terms of release: The scientific or technical validity of this Contract Report is entirely the responsibility of the contractor and the contents do not necessarily have the approval or endorsement of Defence R&D Canada.

Abstract

Previous contracts resulted in the development and use of the program BREVER, which performs reverberation inversion using the sonar analysis suite DMOS (DRDC Atlantic Model Operating System). A more recent contract allowed for the expansion of DMOS to incorporate the use of the ray trace program Bellhop as an alternative to the normal mode theory program PMODES.

The current contract called for the expansion of BREVER so that it is able to use the Bellhop-enabled version of DMOS. A User's Guide for the newly expanded version of BREVER was also to be written as a separate document. Both of these tasks were accomplished.

Initial testing of the BASE 04 sea trial configuration, performed as a prelude to analysis of that data, revealed a limitation of Bellhop previously unknown to both the author and the Scientific Authority. This limitation prevented using the expanded version of BREVER to perform reverberation inversion on the BASE 04 data, which was the last task on the current contract.

Résumé

Des contrats antérieurs ont permis de développer et d'utiliser le programme BREVER, qui exécute une inversion de réverbération à l'aide de la suite d'analyse sonar DMOS (Système d'exploitation de modèle de RDDC Atlantique). Un contrat plus récent a permis d'incorporer dans DMOS le programme de traçage de rayon Bellhop afin qu'il puisse être utilisé à la place du programme de théories du mode normal PMODES.

Le contrat actuel visait l'extension de BREVER afin qu'il soit capable d'utiliser la version Bellhop de DMOS. Un guide d'utilisateur de la nouvelle version étendue de BREVER a été rédigé sous forme de document distinct. Ces deux tâches ont été exécutées.

Les essais initiaux de la configuration des essais en mer BASE 04, effectués préalablement à l'analyse des données, a révélé une limitation de Bellhop que ni l'auteur ni l'autorité scientifique ne connaissaient. Cette limitation a empêché d'utiliser la version étendue de BREVER pour exécuter une inversion de réverbération sur les données BASE 04, qui était la dernière tâche du contrat actuel.

This page intentionally left blank.

Executive Summary

Introduction

The DRDC Atlantic Model Operating System (DMOS) is an evolution of the SWAMI (Shallow Water Active-sonar Modelling Initiative) suite of programs in use at DRDC Atlantic that enables a user to produce modelled reverberation, transmission loss, signal excess, and probability of detection for an active sonar. A reverberation inversion module, BREVER, is associated with the effort.

The original DMOS was based on normal mode theory to predict acoustic propagation conditions. DMOS had been expanded to include ray-theoretic approaches, specifically Gaussian Beam approaches such as used in Bellhop. The current contract called for the expansion of BREVER so that it is able to use the Bellhop-enabled version of DMOS.

Results

The DMOS models that calculate reverberation and transmission loss from eigenrays produce results consistent with the US Generic Sonar Model (GSM). However, differences were demonstrated between results based on GSM versus Bellhop. Though Bellhop has the benefit of modelling range-dependent environments, the eigenrays produced for a ducted environment with the receiver outside the duct indicates unrealistic energy levels outside the duct. The Bellhop eigenray calculations resulted in unrealistically high reverberation levels being predicted. This investigation and discovery prevented using the expanded version of BREVER to perform reverberation inversion of Mediterranean BASE 04 data (which was the last task on the current contract).

Significance

The completion of the inversion software enables investigations on the usefulness of through-the-sensor probing techniques for tactical decision aids.

Future plans

Further minor improvements will be made before using the capability to test the through-the-sensor probing concept with reverberation and echo data collected on the BASE 04 sea trial.

Calnan, C. 2006. *Reverberation Inversion Enhancements Using BASE 04 Data.* DRDC Atlantic CR 2006-046. Defence R&D Canada – Atlantic.

Sommaire

Introduction

Le système d'exploitation de modèle de RDDC Atlantique (DMOS) est une évolution de l'ensemble de programmes SWAMI (Initiative de modélisation de sonar actif en eau peu profonde) utilisé à RDDC Atlantique, qui permet à un utilisateur de modéliser la réverbération, la perte de transmission, le dépassement d'amplitude du signal et la probabilité de détection pour un sonar actif. Un module d'inversion de réverbération, BREVER, est utilisé pour ces travaux.

Le DMOS original était fondé sur la théorie du mode normal pour la prédiction des conditions de propagation acoustique. Le DMOS a été étendu pour inclure des méthodes théoriques appliquées aux rayons, plus particulièrement la méthode des faisceaux gaussiens telle qu'elle est utilisée dans Bellhop. Le contrat actuel visait l'extension de BREVER, afin qu'il soit capable d'utiliser la version Bellhop du DMOS.

Résultats

Les modèles de DMOS qui calculent la réverbération et la perte de transmission des rayons propres produisent des résultats conformes au modèle générique de sonar (GSM) américain. Toutefois, des différences ont été constatées entre les résultats du GSM et de Bellhop. Bien que Bellhop offre l'avantage de modéliser des environnements en fonction de la portée, les rayons propres produits pour un environnement à conduits avec le récepteur à l'extérieur du conduit indiquent des niveaux d'énergie irréalistes à l'extérieur du conduit. Les calculs des rayons propres Bellhop ont produit des prévisions bien trop élevées pour les niveaux de réverbération. Cette étude et cette découverte ont empêché d'utiliser la version étendue de BREVER pour effectuer une inversion de réverbération des données méditerranéennes BASE 04 (qui constituait la dernière tâche du contrat).

Importance

L'achèvement du logiciel d'inversion permet d'effectuer des études sur l'utilité des techniques de sondage au moyen de capteurs en tant qu'aides aux décisions tactiques.

Travaux futurs

D'autres améliorations mineures seront introduites avant d'utiliser le système pour faire l'essai du concept de sondage au moyen de capteurs en fonction des données de réverbération et d'écho recueillies durant l'essai en mer BASE 04.

Calnan, C. 2006. *Améliorations à l'inversion de réverbération à l'aide de données BASE 04.* RDDC Atlantique CR 2006-046. R & D pour la défense Canada – Atlantique.

Table of Contents

List of Tables

List of Figures

1. Introduction

Contractor Reports [1] and [2] describe the creation and use of the program **BREVER**. This is an IDL program that performs an inversion on measured reverberation data in order to obtain the geoacoustic parameters of the seabed in the area in which data were recorded. It operates by using an IDL core (**BREVER** itself) to perform the inversion-related processes and calls various *SWAMI* (Shallow Water Active-sonar Modelling Initiative) programs via a "spawn"-like process to perform the required reverberation modelling. The *SWAMI* programs are executable versions of compiled FORTRAN programs.

Later, another contract resulted in an expansion of *SWAMI* that allowed a user to run the program in a way that used ray theory, via the program **Bellhop**, to calculate reverberation data. As a part of the modification, users may either use *SWAMI* with ray theory or with the original normal mode calculations. The expansion resulted in some new input files and programs, as well as the modification of existing input files and program modules. With the addition of **Bellhop** the suite of programs was no longer restricted to shallow water cases. This made the suite's name, *SWAMI*, incorrect, so the entire suite was renamed *DMOS* (DRDC Atlantic Model Operating System).

Reference [3] is the Contractor's Report on the expansion of *SWAMI* to *DMOS* by the inclusion of **Bellhop**. That project also necessitated the creation of [4], a comprehensive *DMOS* User's Guide, which is an update of the older *SWAMI* User's Guide.

These latter two references contain background information on both *DMOS* and the program **Bellhop**, which was incorporated into *DMOS* to produce the eigenray data used by other *DMOS* modules. This background information is presented partly in those references and partly in other documents listed in their bibliographies.

The current contract was awarded to expand the program **BREVER** to allow a user to use the enhanced, ray theory version of *DMOS* as an alternative to the normal mode version.

However, before the expansion of **BREVER** could be performed a leftover concern from the *DMOS* enhancement documented in [3] had to be cleared up. The problem was that the reverberation data produced by the enhanced *DMOS* from eigenrays had not been properly compared to similar data produced by any other models. In other words, *DMOS* had to be verified. After this verification was done **BREVER's** abilities were expanded to allow the use of **Bellhop**.

One of the current contract's requirements was that once **BREVER** was expanded, a User's Guide was to be written for the new version of the program. This was done, and the new guide is available as reference [5].

The upgraded version of **BREVER** was to be used to perform reverberation inversion on data collected during the BASE 04 sea trials. The geoacoustic seabed parameters so obtained were then to be used to model transmission losses. These results would have been compared to transmission loss data produced from analyses of the BASE 04 data.

As it turned out, testing for the BASE 04 setup uncovered limitations in **Bellhop** that were unknown to both the author and the Scientific Authority. Ultimately these limitations prevented the use of the enhanced version of **BREVER** in performing a reverberation inversion on the BASE 04 data.

Consequently, the rest of this report contains the following sections:
- 2 - Discusses and describes the *DMOS* verification
- 3 - Describes the **BREVER** expansion
- 4 - Indicates where to get the **BREVER** and *DMOS* programs
- 5 - Describes the discovery of **Bellhop's** failure and gives some information related to this failure

Besides common English typographic conventions, the following conventions are used in this document:
- **bold text** is used for filenames (e.g. **test.pro** or **/local/files/test.pro**)
- ***bold italics text*** is used for directories (e.g. ***/usr/tmp***)
- *italics* text is used for computer and program suite names (e.g. *Tessie* and *DMOS*)
- **Bold Arial text** is used to indicate program names (e.g. **BREVER**, **Bellhop**)
- Arial text is used to indicate function and subroutine names (e.g. PPR_SETUP)
- *italic Arial text* is used for variables' names in computer programs or associated with operating systems (e.g. *IDL_PATH*)
- `Courier text` is used for text to be typed on the keyboard, code or file listings, etc. (e.g. enter "`idl`")

2. *DMOS* Verification

It was decided to verify the *DMOS* reverberation and transmission loss results to ensure that the modified *DMOS* code was working properly. This would be done by comparing *DMOS's* output with the results produced by two other programs, **Bellhop** and **GSM**.

Bellhop is able to produce a file that can be converted to a **GSM**-like eigenray file, as well as transmission loss files. The idea was to have *DMOS* use **Bellhop's** "eigenray data" to calculate reverberations, which it then used to calculate transmission loss results. The *DMOS* transmission loss results could be compared with those produced by **Bellhop**.

Later on it was decided to use **GSM** to produce both eigenray files and reverberation data directly, and then have *DMOS* use the **GSM** eigenray files to calculate its own reverberation values. The two sets of reverberation results could then be compared. This had an advantage over the **Bellhop** test sequence in that using **GSM** allowed the comparison of "intermediate" reverberation data.

Finally, **GSM** was made to produce transmission loss data, which could be compared with the analogous data produced by *DMOS* from eigenrays calculated by both **GSM** and **Bellhop**.

Figure 1 shows how the various programs involved in the verification process are related in terms of which program produces what type of output and how one program's output is used by another program.

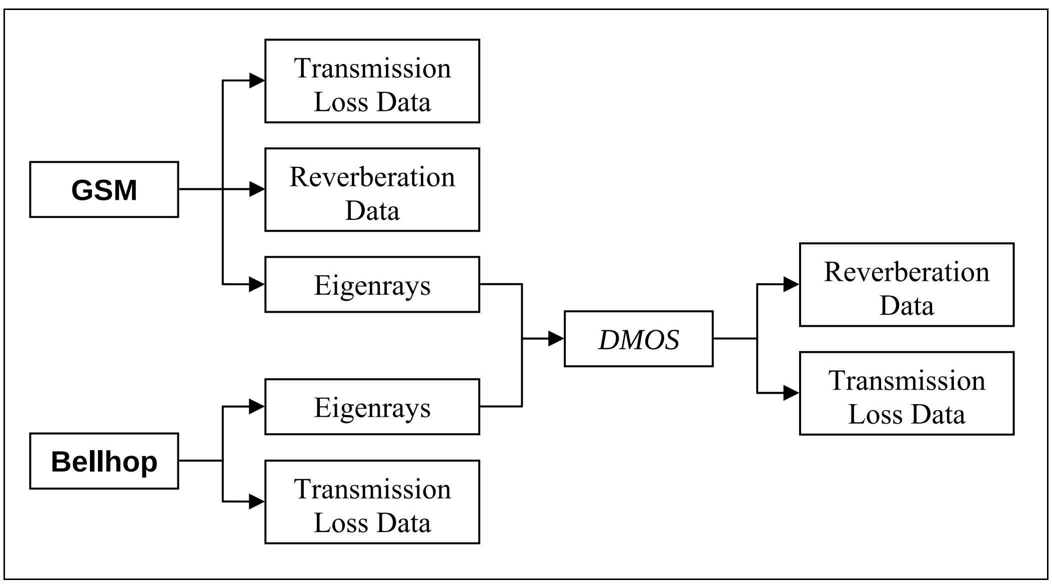

Figure 1. Eigenray Related Programming Chain and Outputs

The setup decided upon for the verification testing consisted of:

- 100 metre deep water over a flat bottom
- Onmidirectional transmitter and receiver
- MGS province of 1 for the programs that use this datum
- bottom scattering strength of -27 for the programs that use this datum
- source level of 210 dB
- two different sound speed profiles were used for two sets of tests; the profiles' values are described in the sections that use them

2.1 Reverberation Calculation Problem

As was mentioned in Section 1, it appeared that the reverberation results produced by *DMOS* based on **Bellhop's** eigenrays were incorrect. This was based on a comparison of *DMOS* reverberation results calculated from its two sources: **PMODES's** normal mode theory and **Bellhop's** eigenrays. These results are displayed in Figure 2.

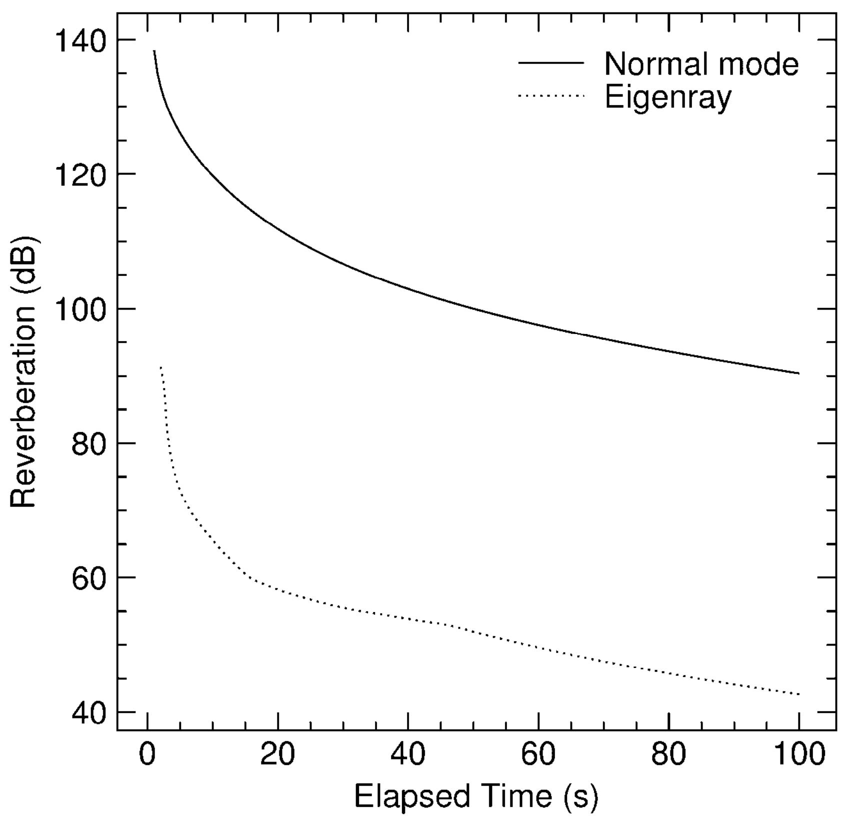

Figure 2. *DMOS* Normal Mode and Eigenray Reverberation

Although the shapes of the curves are similar, they are separated by much too large a difference for any explanation other than that the eigenray values are incorrect. The underlying assumption about the eigenray reverberations being incorrect is that the normal mode reverberations are correct, or at least “more correct.” Since the normal mode results have often been tested and successfully used over the years this assumption seems valid.

The differences between the two sets of reverberation values were calculated and is presented in Figure 3.

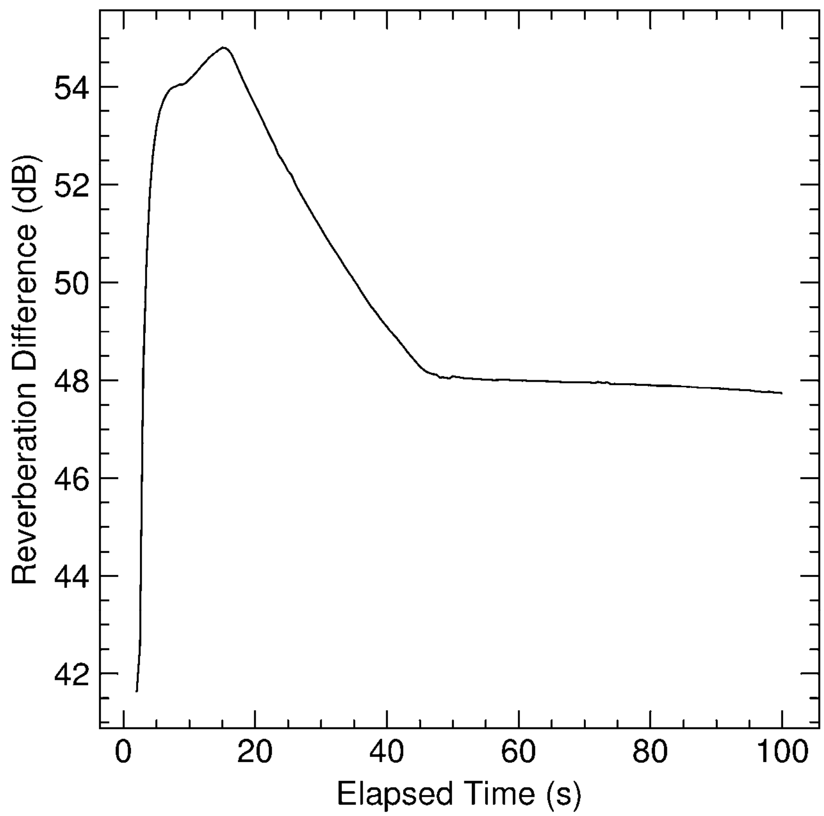

Figure 3. *DMOS* Normal Mode minus Eigenray Reverberation

This figure was produced in order to see if the amount and trend of the differences between the two sets of reverberation results would give any hint as to the reason for their differences. Other than showing that the difference was indeed large and that the sets of values were fairly parallel after about 46 or 47 seconds, nothing else useful was obtained from the figure. Progress was hampered somewhat by the fact the **Bellhop** does not produce reverberation results, and so there was no baseline that could be compared to the *DMOS* eigenray-based reverberations.

At the suggestion of the Scientific Authority the program **GSM** was used to produce both reverberation data and the associated eigenrays. The calculation of reverberation from eigenrays in **GSM** was traced to the subroutine CMPRV1, and was the subroutine PC_EIGEN in the *DMOS* module **MONOGO**. Accordingly, with the insertion of copious PRINT statements into these subroutines and a line-by-line examination of the code, the problems with PC_EIGEN were eventually discovered and repaired. Once the code was fixed, a structured set of comparison tests was run to verify the corrected PC_EIGEN code.

2.2 Reverberation Comparisons: Test 1

The scenario described in Section 2 was used with a sound speed of 1500 m/s at all depths. This test will be referred to as "constant sound speed profile" or "CSSP" case. **GSM** was again used to produce both a reverberation time series and the associated eigenrays, which were used by *DMOS* to calculate its own reverberation results. As well, **Bellhop** was used to produce eigenrays, which *DMOS* also used to produce reverberation results. *DMOS* was also used to produce reverberation results using normal mode theory via its module **PMODES**. The various reverberation data sets are plotted together in Figure 4. It may be noted that the figure has no curve for reverberation data produced directly by **Bellhop**. This curve is missing because **Bellhop** does not produce this parameter.

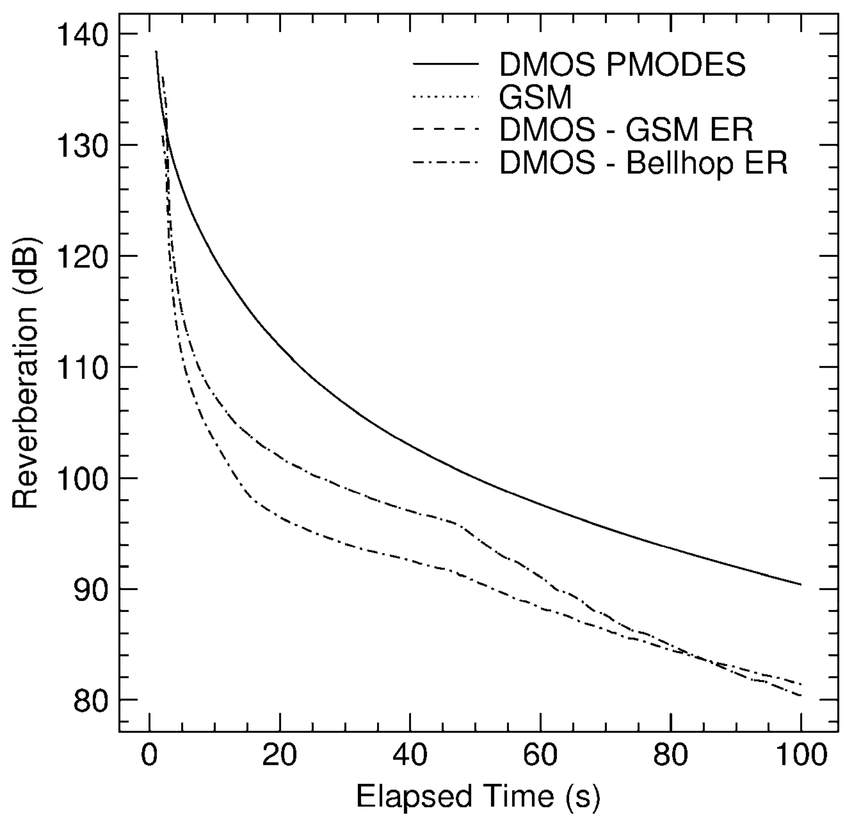

Figure 4. CSSP Reverberation Comparison

What is not immediately obvious from examining Figure 4 is that the plotted reverberation data produced by **GSM** (labelled "GSM") and *DMOS* using **GSM's** eigenrays (labelled "DMOS – GSM ER") are practically on top of each other. (At 40 seconds this "combined" curve forms the middle line of the plot.) To help separate the data, the Figure 4 "DMOS – GSM ER" data were subtracted from the "GSM" data. The results were plotted in Figure 5.

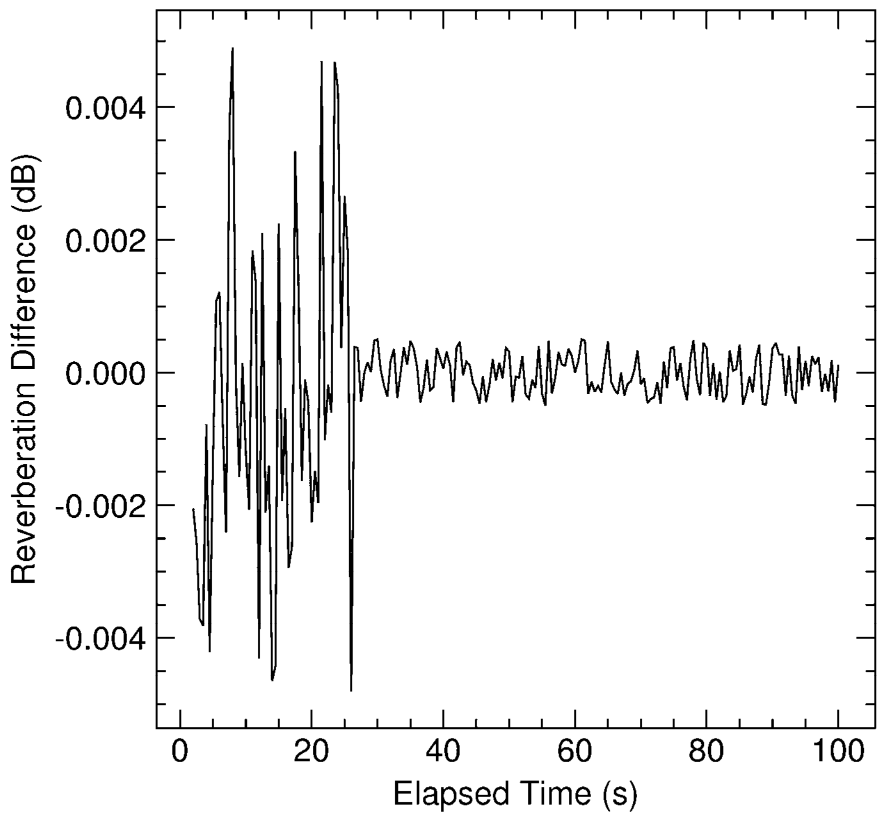

Figure 5. CSSP Reverberation Difference: "GSM" minus "DMOS - GSM ER"

The differences between the two curves are so small that they may easily be attributed to the two programs using slightly different analysis techniques and *DMOS* using double precision variables for a number of calculations and summations, rather than the single precision variables used by **GSM**.

The fact that **GSM** and *DMOS* (using the same eigenray data as input) produce essentially the same reverberation results suggests that *DMOS* is now calculating reverberation correctly, or at least in a manner consistent with **GSM's** technique.

Another analysis made with Figure 4 data was to calculate the difference between the "GSM" reverberation data and the "DMOS – Bellhop ER" data. The resulting differences are presented in Figure 6. This was done to see how reverberation results from the two eigenray-producing models differ.

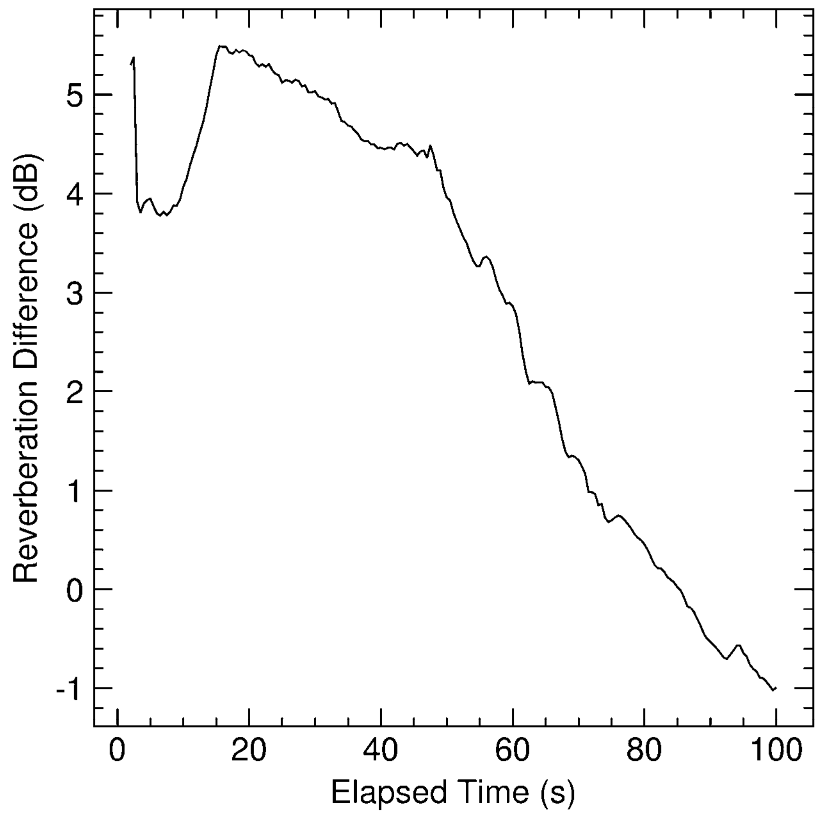

Figure 6. CSSP Reverberation Difference: "GSM" minus "DMOS - Bellhop ER"

This plot indicates that the maximum difference between the two sets of reverberation values is about 5.5 dB. In combination with the Figure 5 results, this suggests that the difference between **GSM** and **Bellhop** related reverberation values is due to differences in the eigenray data calculated by the two programs.

It was noted that the eigenray-based reverberation data of Figure 4 all have a "kink" near 47 seconds, something reflected to a lesser extent in Figure 6 as well where its slope changes. The hypothesis was put forward that this might be due to the sound speed having a constant value over the entire water column, a condition that adversely affects some models. This idea was tested, with the results shown in the next section.

2.3 Reverberation Comparisons: Test 2

A second test was made to calculate reverberation values. All parameters were identical to those of test 1 except for the sound speed profile. In this case the sound speed was set to 1500 m/s at the surface and 1501 m/s at the bottom depth of 100 m.

This test will be referred to as “slanted sound speed profile” or “SSSP” case. Since only these two values were used as input, the programs all presumably interpolated speeds for all other depths.

Figure 7 is analogous to Figure 4, and shows reverberation results from the same processing streams as in the earlier figure.

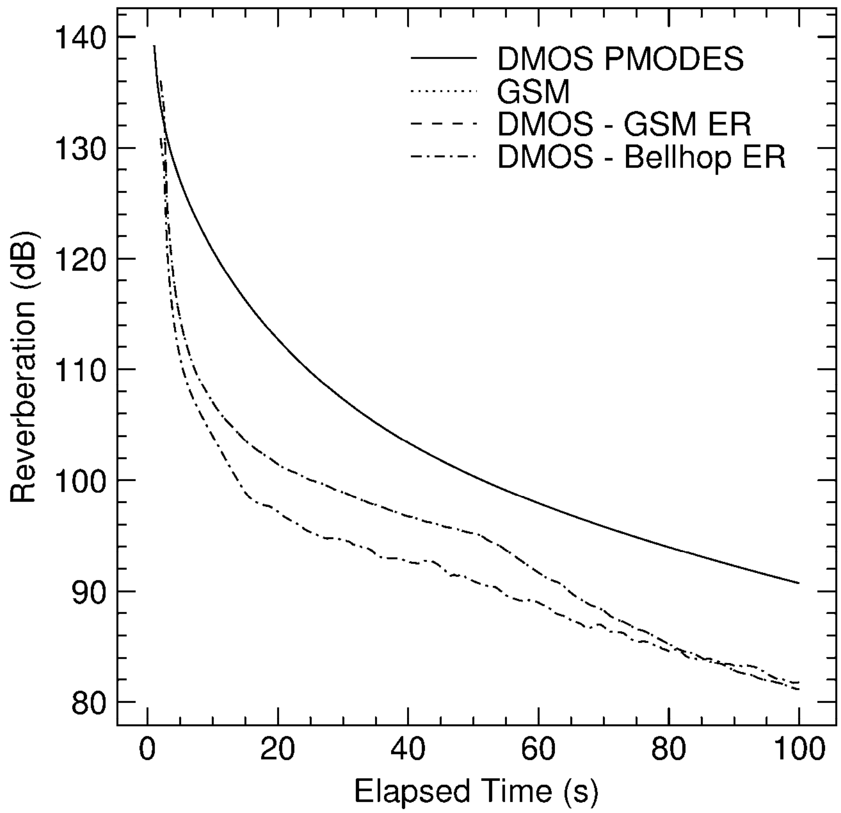

Figure 7. SSSP Reverberation Comparison

Once again the reverberation values produced by “GSM” and “DMOS – GSM ER” eigenrays are essentially identical; together they form the middle line at 40 seconds. The differences between the two lines were again calculated and are presented in Figure 8.

Figure 7 shows that the **GSM**-related reverberation data are again greater than the **Bellhop**-related values, and there is still a kink in the curves. The kink, however, has moved somewhat and is now at a time of slightly over 50 seconds. This means that the fact of the kink is not due to the iso-speed profile, but its position could very well be dependant on the speed gradient.

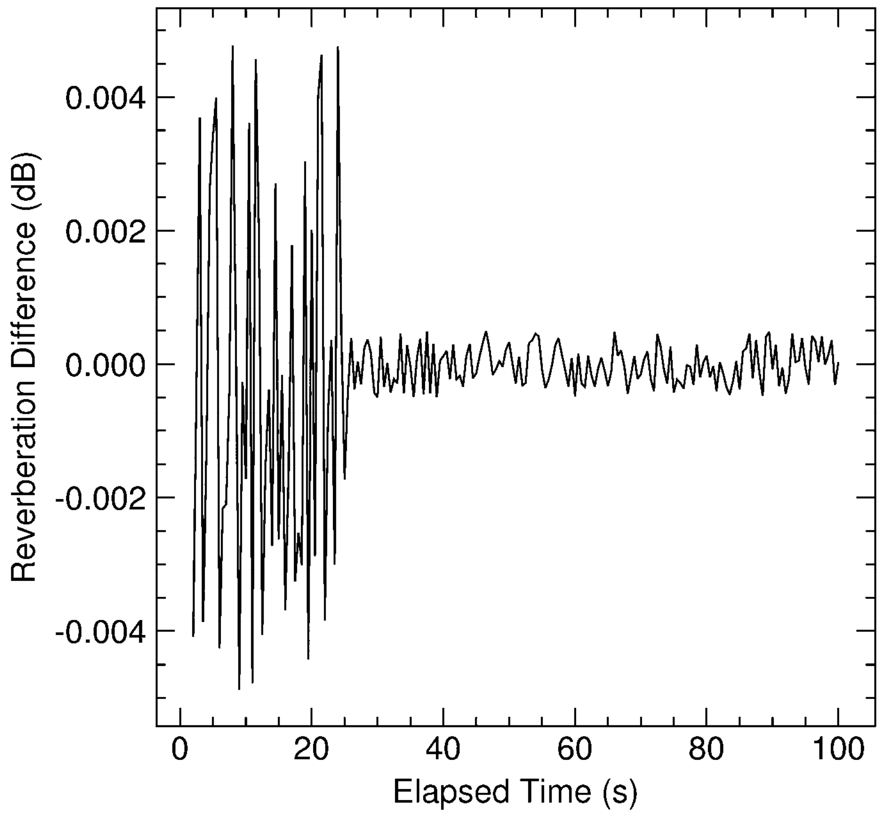

Figure 8. SSSP Reverberation Difference: "GSM" minus "DMOS - GSM ER"

As can be seen in the above figure, the "GSM" and "DMOS – GSM ER" differences are greatest below times of about 27 seconds. At longer times the differences are smaller, but even the greater differences are quite small.

Another change of note is that the **Bellhop** values do not form as smooth a curve as they did initially; this time there is a noticeable oscillation starting at about 15 seconds. The following figure presents the difference between the "GSM" and the "DMOS – Bellhop ER" curves of Figure 7.

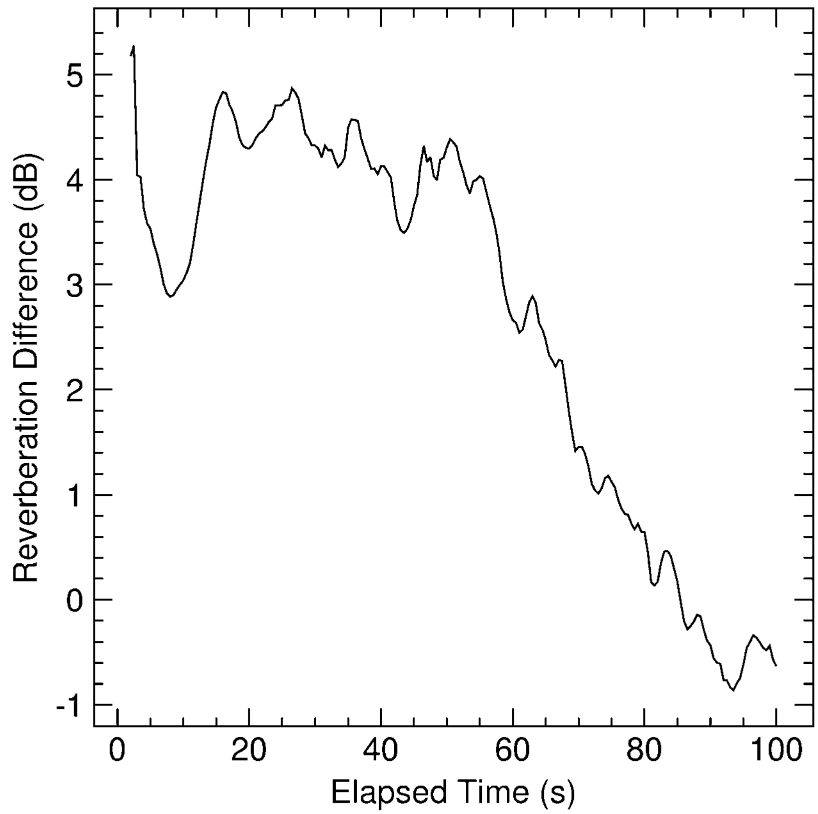

Figure 9. SSSP Reverberation Difference: "GSM" minus "DMOS - Bellhop ER"

Figure 9 has more, and more pronounced, vertical oscillations than its test 1 analogue, Figure 6. These oscillations are due to the shape of the **Bellhop** reverberation data curve, as seen in Figure 7. The reason for this difference in the **Bellhop** curve was not determined since examinations of **Bellhop's** operation were outside the scope of the current contract.

2.4 Test 1 and 2 Reverberation Comparisons

Displayed in Figure 10 are the reverberations produced by *DMOS* using both **GSM** and **Bellhop** produced eigenrays for tests 1 and 2. The *DMOS* normal mode and the **GSM**-produced data have been omitted, the latter since the values are identical to the *DMOS* data that use **GSM** eigenrays.

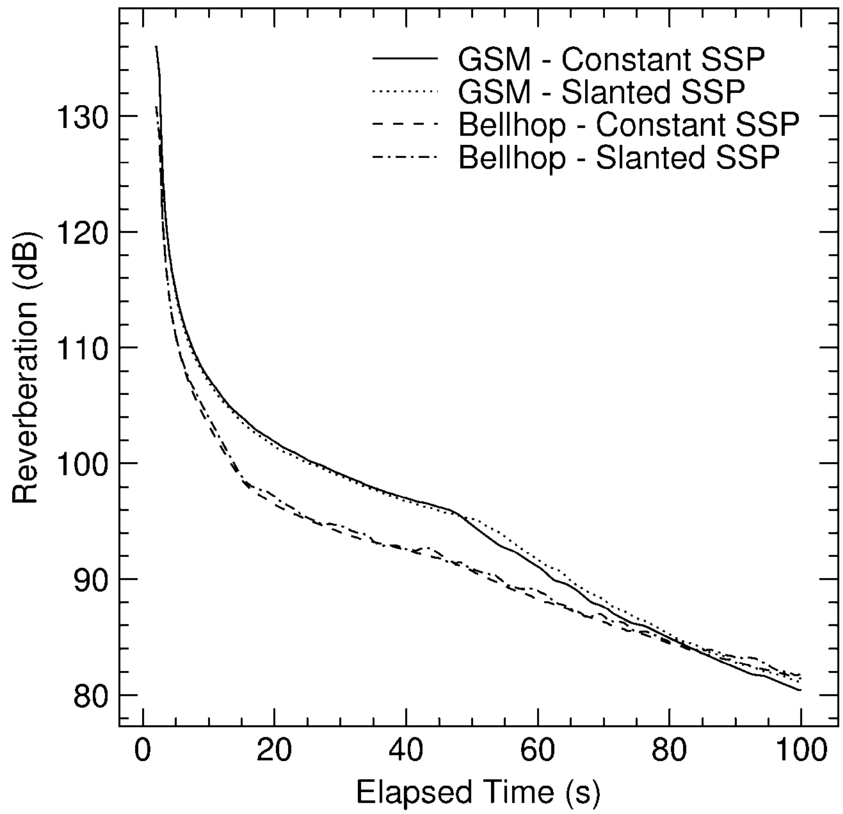

Figure 10. *DMOS*-produced Eigenray-based Reverberation Results

This figure more clearly shows the way that the reverberation based on **GSM** and **Bellhop** eigenrays change from test 1, with a constant value sound speed profile, to test 2, with a slanted sound speed profile.

The different positions of the **GSM** kink and the change in smoothness of the **Bellhop** curve are clearly seen, and the nature of these changes suggests that the two programs use different methods to calculate eigenrays.

2.5 Transmission Loss Comparisons: Test 1

Transmission loss was calculated in five ways using the test 1, or constant sound speed profile, data sets. Modelled data were calculated by **GSM**, **Bellhop** (which will produce transmission loss output, although not reverberation), and by *DMOS* in three ways: using normal mode theory via the program **PMODES**, using eigenrays produced by **GSM**, and using eigenrays produced by **Bellhop**. Figure 11 displays the resulting data.

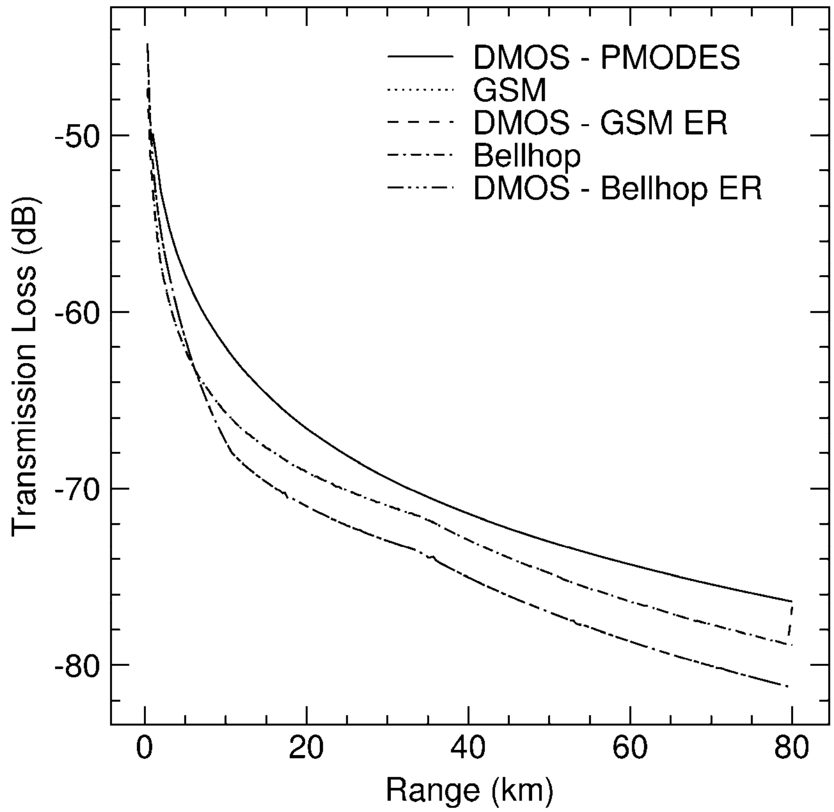

Figure 11. CSSP Transmission Loss Comparison

What is not immediately obvious from this figure is that the data produced by *DMOS* from **GSM** and **Bellhop** eigenrays are essentially identical to the data produced by **GSM** and **Bellhop** themselves. (The two **GSM**-related lines form the middle line at 40 km while the two **Bellhop**-related lines form the bottom line at 40 km.) This indicates that the method used by *DMOS* to produce transmission loss from eigenrays is identical, or at least equivalent, to the methods used by **GSM** and **Bellhop**. It also means that the **GSM** and **Bellhop** calculations are also equivalent.

The fact that the transmission loss data from **GSM** and **Bellhop** are different implies that the eigenray data produced by the programs are different. This is something that was also implied in the reverberation results from the two programs.

One oddity noticeable in Figure 11 is at the end of the “DMOS – GSM ER” curve. For unknown reasons the last two points rise significantly higher than those preceding them, making the curve end on a sharp upwards spike.

Since the eigenray results are the primary focus of these tests, with the normal mode data being presented only for comparison reasons, the differences between the *DMOS* produced **GSM**-based and **Bellhop**-based transmission loss values were calculated. The results are presented in Figure 12. These data were chosen rather than the data from the "parent" programs **GSM** and **Bellhop** since **BREVER** will be using *DMOS* output. As well, the *DMOS* results are, to all intents and purposes, identical to the parent programs' results.

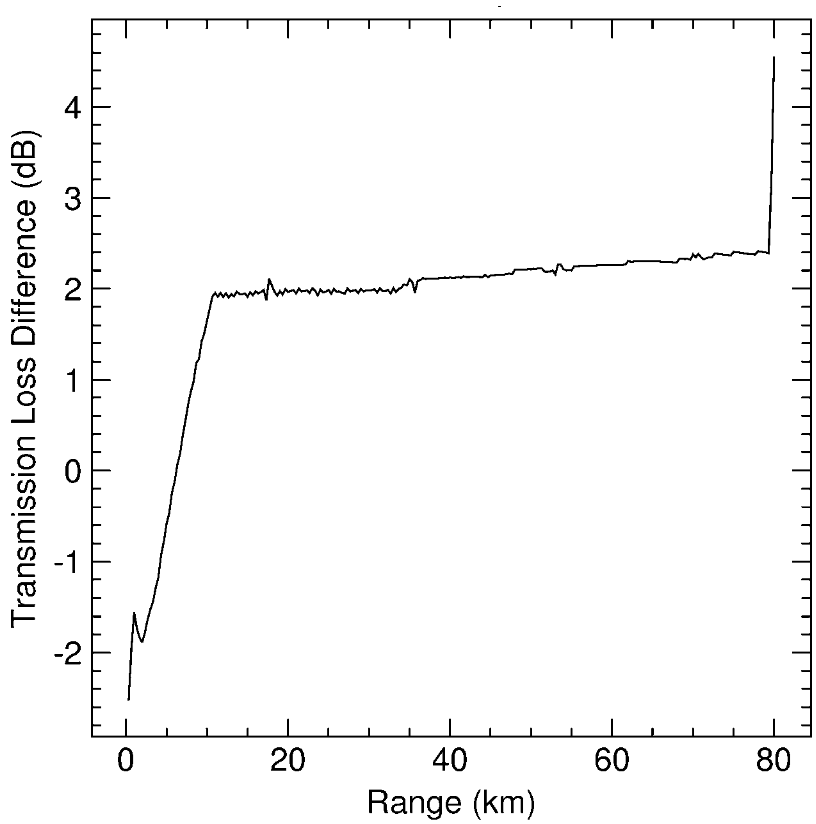

Figure 12. CSSP Transmission Loss Difference: GSM minus Bellhop

It can be seen that for the majority of the distance range the difference is about 2 dB. There is a spike at the start where the data curves cross, but they remain almost parallel for the rest of their run. The spike at the end of the curve is due to the "DMOS - GSM ER" case having its last two values rise unexpectedly.

2.6 Transmission Loss Comparisons: Test 2

The transmission loss was also calculated using the test 2, or slanted sound speed profile, data sets. As in the case of reverberation, this was done to see if any anomalies in the results might be due to the unchanging sound speed of test 1. Figure 13 has the results.

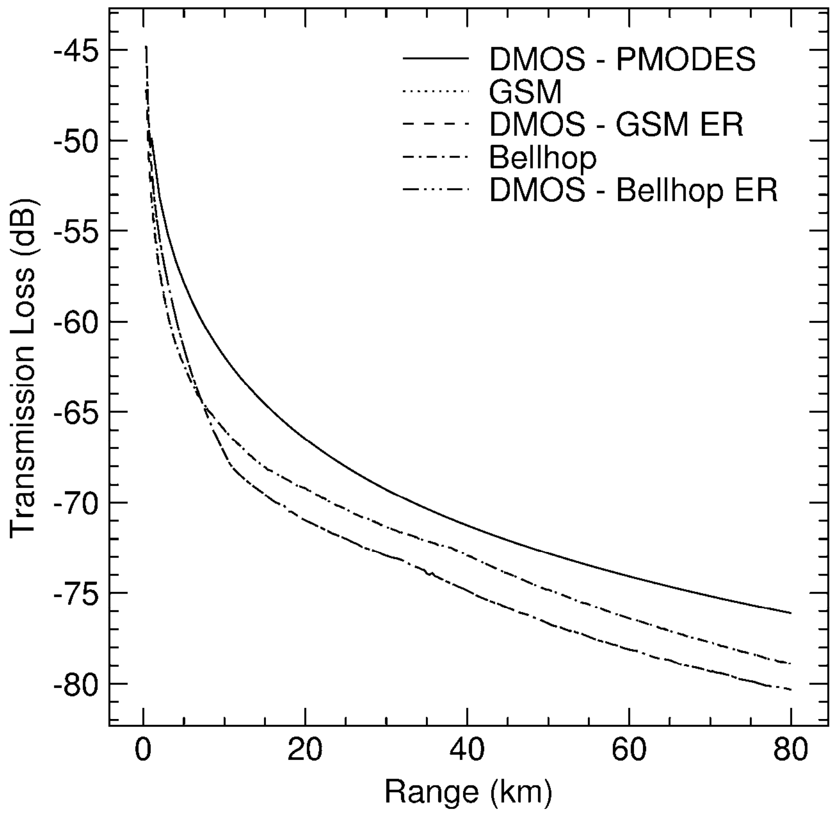

Figure 13. SSSP Transmission Loss Comparison

Once again the *DMOS*-produced curves are essentially identical to those of the programs that produced the eigenrays used by *DMOS*. (The two **GSM**-related lines form the middle line at 40 km while the two **Bellhop**-related lines form the bottom line at 40 km.) The main difference with Figure 11 is that the "DMOS – GSM ER" curve doesn't spike upwards at the end.

The differences between the "DMOS – GSM ER" and "DMOS – Bellhop ER" transmission loss results were again calculated to see if anything untoward or significant would be revealed. The differences are presented in Figure 14.

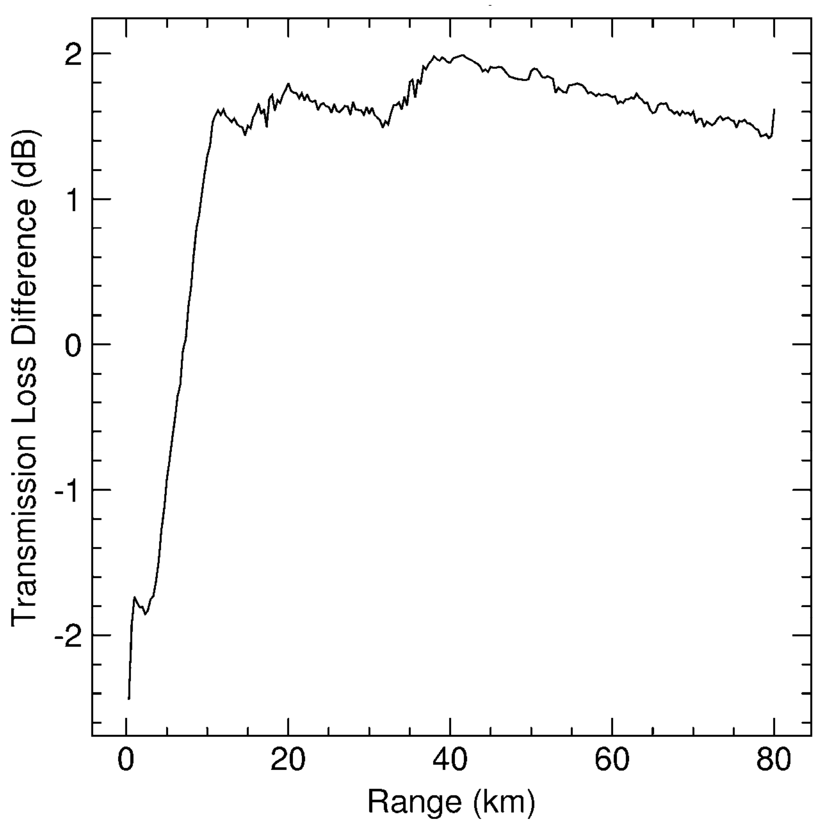

Figure 14. SSSP Transmission Loss Difference: GSM minus Bellhop

These results are, in general, very similar to the test 1 results presented in Figure 12. The main differences are the greater variability in the plateau part of the curve and the missing spike at the maximum range. The missing spike is due to the "DMOS – GSM ER" curve not increasing sharply at the end, but continuing on its downward trend.

The average of the plateau values was calculated to be 2.15 dB for the constant sound speed profile case and 1.69 dB for the slanted sound speed profile case. It is not known at this time whether this difference has any significance.

2.7 Test 1 and 2 Transmission Loss Comparisons

All the eigenray-based *DMOS* transmission loss data were plotted together and are presented in Figure 15.

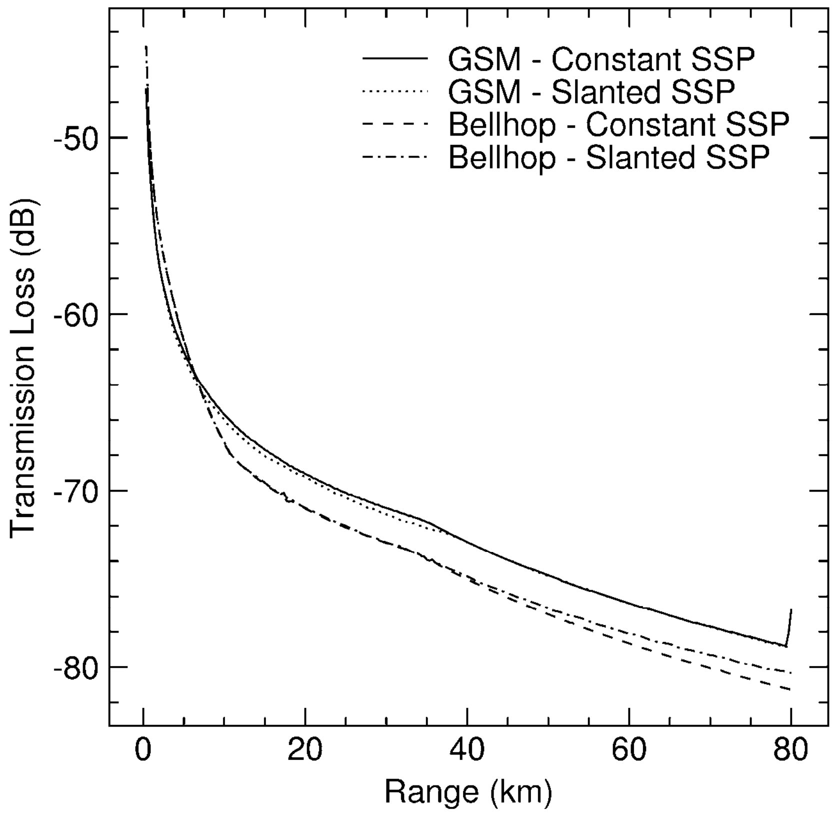

Figure 15. ***DMOS*-produced Eigenray-based Transmission Loss Results**

A couple of features may be noted on this plot. The first is that the two **GSM**-based plots are only slightly different until they meet up after their respective kinks. The kink in the slanted SSP case occurs at a greater range than that of the constant SSP case, but for the last half of the ranges the transmission losses are extremely close together if one ignores the spike at the end of the constant SSP case.

The second point is that the **Bellhop**-based curves are extremely close together until the region of the kinks is reached. After that, the curves diverge, with the slanted SSP case having a lesser amount of transmission loss.

2.8 Verification Test Conclusions

A number of conclusions may be drawn from the figures presented in Section 2.

1. Using **GSM**-produced eigenray input, *DMOS* can produce reverberation data essentially equivalent to that of **GSM**.

2. Using **GSM**-produced eigenray input, *DMOS* can produce transmission loss data essentially equivalent to that of **GSM**.

3. Using **Bellhop**-produced eigenray input, *DMOS* can produce reverberation data approximately similar to that of **GSM**.

4. Using **Bellhop**-produced eigenray input, *DMOS* can produce transmission loss data essentially equivalent to that of **Bellhop**.

5. The above points suggest that *DMOS* handles eigenrays in a similar manner as both **GSM** and **Bellhop**, both of which handle eigenrays in a similar manner.

6. All differences between **GSM** and **Bellhop** based results appear to be due to differences in their eigenray files. This implies that these two programs calculate eigenrays in different ways, as is exemplified in Figure 15 where the transmission loss curves from **GSM** come together over distance, while the **Bellhop** curves start diverging.

The last point might be worth investigating, but this work is beyond the scope of the current project and so will be ignored for the present. It might also be instructive to determine the nature of the kinks that appear in the reverberation and transmission loss figures, but that, too, is outside of the current project's scope.

What was demonstrated satisfactorily, however, is that *DMOS* is operating properly in its use of eigenray data for the production of both reverberation and transmission loss data, which was the main point of these verification tests.

3. BREVER Expansion

The initial requirement for expanding **BREVER** was to devise a way to tell the program whether it would be using normal mode or eigenray input data, produced by, respectively, **PMODES** and **Bellhop**. Once this was accomplished, the other procedural details that resulted from the addition of eigenray input would be dealt with as they occurred.

While the **Bellhop**-enabled version of **BREVER** was being tested and debugged, however, a consequence of the program's design became apparent. **BREVER** was written to minimize the differences between a measured and test slope, but although the slopes were matching quite well, the actual modelled reverberation values used to calculate the slopes were occasionally very different from the baseline comparison values. After some consideration, a simple way was devised to help reduce this effect: energy weighting.

This scheme was added to **BREVER** and so became an unplanned part of the program's expansion. The following subsection goes into greater detail on how this scheme works, which requires a brief description of how **BREVER** operates at a gross level.

3.1 Energy Weighting

Before describing how the non-**Bellhop** related energy weighting expansion was implemented, a little background is required on how **BREVER** works.

BREVER initially reads in what is referred to as the "measured reverberation data," although the data may in fact have been created by a model. The data are referred to in this way since the original intent was to run the program using measured data as the basis of comparison. However model data were used in testing since the accuracy of the program's results is easier to determine when the values of the geoacoustic parameters that were used to create the "measured" data are known.

Regardless of their origin, the values in the measured data are used to calculate the point-to-point slope of the data's curve. **BREVER** iteratively makes a series of estimates for the geoacoustic data parameters that result in the calculation of its own test reverberation time series, the point-to-point slope of which is then calculated. The slope of the measured data is compared to that of the test data, and the parameters are varied so as to cause the test data's slope to match the measured data's slope as closely as possible.

(It should be noted that the term "slopes" is somewhat of a misnomer. To be absolutely correct the slope would be calculated by subtracting a reverberation value from its neighbour and then dividing the difference by the time difference between the two data points. However since the measured and test data both occur at the same times, which are a constant time apart, the program doesn't bother dividing the reverberation differences by the time difference. Since dividing the differences by a constant value would only scale both sets of differences by the same constant amount, it was not deemed necessary to perform this extra calculation. No effective difference in the ultimate results occurs due to omitting the division.)

The program calculates a goodness of fit score (called the "energy") for a particular test data set by summing the absolute values of the differences of simultaneous slope values, i.e.:

$$Energy = \Sigma|[Measured\ slope(i) - Test\ slope(i)]|$$

The value of *Energy* will decrease as the test slope values approach the measured slope. A "best fit" set of parameters is declared to have been achieved when either the two sets of slopes are within a desired tolerance limit, as defined by having the *Energy* reaching a pre-defined tolerance limit, or a maximum number of test parameter data sets have been tried. At this point the results are printed out and the program exits.

However, during the testing and debugging phase of the program's enhancement it was noted that although the slope of the measured reverberation data were being matched quite well, a look at the actual reverberation data indicated something quite different. The measured and best-fit test reverberation data curves were parallel (as would be expected since the slopes were being matched), but the curves could be any distance apart. It was foreseen that this might not be desirable, depending on the ultimate use of the results, and so a way was devised to reduce the offset between the measured and best-fit test reverberation data.

To calculate the fit between the reverberation data, a scheme analogous to the slope fitting was used. If the previous *Energy* is referred to as $Energy_{SLOPE}$, then an energy value defining the fit of the reverberation data may be defined as:

$$Energy_{REVERB} = \Sigma|[Measured\ reverberation(i) - Test\ reverberation(i)]|$$

Then, to use both energies to determine a fit, a weight would be assigned to each of the energies to calculate an overall combined energy, via:

$$Energy_{TOTAL} = (weight_{SLOPE} \times Energy_{SLOPE}) + (weight_{REVERB} \times Energy_{REVERB})$$

The minimization of $Energy_{TOTAL}$ would result in the combined best fit. The original operation of **BREVER**, which only calculated and used $Energy_{SLOPE}$, can be reproduced by setting $weight_{REVERB}$ to zero and $weight_{SLOPE}$ to a value greater than zero. The two weight values are part of the input to **BREVER**, as described in [5].

Users of **BREVER** must remain aware of the fact that the actual reverberation values will tend to be appreciably larger than the slope values calculated from them. This means that setting $weight_{REVERB}$ and $weight_{SLOPE}$ to the same values does not result in both parameters having the same influence on $Energy_{TOTAL}$. To achieve this, the weights would have to be given values inversely related to their relative energies.

Guidance for values to use for these parameters is difficult to attempt since reverberation and slope values will vary on a case-by-case basis. However, since the slope is normally the primary focus of the solution, it would be wise to make its energy weight appreciably larger than that of the reverberation data.

3.2 Code Changes

Ultimately all changes to the running of **BREVER**, at least as far as a user is concerned, are reflected in the **BREVER** input file described in reference [5]. **BREVER** enhancements, both for energy weighting and **Bellhop** usage, required changes to a number of the individual routines that comprise the program. The following table lists the modified routines and briefly describes the changes made to them.

Table 1. BREVER Code Changes

Routine	Changes Made
brevercom.pro	This is an "include" file of variables that are used in a number of routines. The most important changes are the addition of: • *c_TLMODEL*: the name of the transmission loss model (**PMODES** or **Bellhop**) • the $Energy_{REVERB}$ weighting factor • the $Energy_{SLOPE}$ weighting factor • the measured reverberation data Other changes made include: • variables that were originally only used in one or two related routines were moved here • variables needed as flags for transmission loss model-specific operations were created • some variables were renamed
brever.pro	This is **BREVER's** main routine and changes to it included: • added a check of the value read in for *c_TLMODEL* • moved all **PMODES**-specific code into an "`IF`" branch based on *c_TLMODEL's* value • wrote **Bellhop**-specific code reached via *c_TLMODEL* The *c_TLMODEL*-specific code dealt with processing, output contents, and formatting.
read_brever_in.pro	This function reads in the main **BREVER** input file. The method in which this file is read in was modified, something necessitated by the changes to the file's format. Then the list of items read in was expanded to allow **Bellhop**-required data.
read_desinfo.pro	This function reads in *DMOS* **.des** files. It was modified to reflect changes to the **.des** file's gradient information line.

Routine	Changes Made
read_temp_env.pro	This function reads the template **.env** file. In it the name of a **brevercom.pro** variable was changed.
bs_setup.pro	New routine that produces an input file for **BellhopDMOS**, the program that runs **Bellhop**.
read_meas_data.pro	This function reads measured data. Some variables were renamed and the read-in measured reverberation data were put into a **brevercom.pro** variable.
ppr_setup.pro	This function sets things up for a new points/radial set of calculations. New **Bellhop**-specific code was written and it was separated from the existing **PMODES** code by checking *c_TLMODEL*.
cost.pro	This function calculates the energy cost of a reverberation time series. New **Bellhop**-specific code was written and it was separated from the existing **PMODES** code by checking *c_TLMODEL*. Also added the energy weighting code.
make_des_file.pro	New routine used to create **MONOGO's** input **.des** files. The **PMODES** part of this routine was formerly contained in **cost.pro**.
ri_simplex_init.pro	This function initializes data arrays for the simplex part of the ASSA process. New **Bellhop**-specific code was written and it was separated from the existing **PMODES** code by checking *c_TLMODEL*.
ri_amoeba.pro	This function performs the "amoeba" part of the ASSA process. New **Bellhop**-specific code was written and it was separated from the existing **PMODES** code by checking *c_TLMODEL*.
write_out_hdr.pro	This function writes the header information to the output file. New **Bellhop**-specific code was written and it was separated from the existing **PMODES** code by checking *c_TLMODEL*.

3.3 BREVER Solution Parameters

It is the nature of inversion programs, including **BREVER**, that the program can only solve values for parameters that are used in calculating the test data set to be compared to a baseline set of values.

BREVER uses the *DMOS* suite of programs to produce reverberation data, a derivation of which is compared to a measured baseline data set. Based on a user's choice *DMOS* will use one of two models in the production of reverberation data: **PMODES** or **Bellhop**. Table 2 indicates the geoacoustic parameters that the two programs use to calculate reverberation and which therefore can be solved for.

It should be noted that **BREVER** allows a user to set fixed values for any of the parameters so that it will not be searched for. (The means for doing this are described in the User's Guide, [5].) The following table, therefore, indicates the parameters that **BREVER** *may* be requested to solve for, not those that it will always solve for. In fact, if a user so desires, all searchable parameters may be set to fixed values and the program will not search for anything, but will only produce an energy value for the chosen parameter values.

Table 2. BREVER Reverberation Parameter Usage

Parameter	PMODES	Bellhop
Points/radial	✓	✓
Bottom Density	✓	
Compressional Sound Speed	✓	
Compressional Attenuation	✓	
Scattering Strength	✓	✓
Depth	✓	✓
MGS province Number		✓

Disregarding the parameters in common between the transmission loss models, **PMODES** usage can solve for three parameters that **Bellhop** does not solve for and **Bellhop** usage can solve for one parameter that **PMODES** does not solve for. A user should be aware of this difference as it may influence the **BREVER** solution mode to be used. In other words, if a user wishes to solve for the "**PMODES** parameters," then using **BREVER** with **Bellhop** will be of no use.

4. Program File Locations

BREVER

The most recent version of the **BREVER** code is located on *Tessie* in the directory ***~calnan/IDL_code/BREVER***.

Users should be aware that a number of IDL functions in this directory have names that appear in other directories, **read_dat_dat32.pro**, for example. Some of these "same-name" routines are identical but others are not. Initially the same routines were copied from directory to directory so that any given directory would contain all the code it needs. This is still the case, but some of the routines have been edited according to the requirements of the main program they support. In the majority of cases the changes were enhancements rather than changes in functionality, but these changes occasionally necessitated altering the parameters passed to the functions. The ultimate intent is to have the contents of every same-name function identical regardless of where they appear, but this has not yet been done.

The reason for this notice is to warn users that if they copy **BREVER's** code from the location appearing above, they should copy all the files in that directory and not just the ones that they don't already have. The versions they may already have could have come from a different directory and so be different from the ones used by **BREVER**.

DMOS

The most recent versions of the *DMOS* executables are located on *Tessie* in the directory ***~calnan/projects/RevInv/dmos/bin***. However once sufficient testing has been performed and the author and Scientific Authority are satisfied that *DMOS* is working properly the executables will be moved to a subdirectory of ***/local/models/DMOS*** on *Tessie*. The executables were produced by the GNU **g77** compiler for Intel-based Linux, but if a user needs to compile the programs for a different platform the programs' source code is located in directories near the executables, with each program's code in a separate directory.

Speciation has also occurred with some source code files used by multiple *DMOS* programs, as it has in the IDL code, and for the same reasons. Once again the intent is that ultimately the routines will be "rationalized," but for now if a user copies the source code in order to produce a new executable, care must be taken to use only the code in that program's subdirectory. In general the differences are between subroutines used by **MONOGO** and **EXCESS1**, which use eigenray files, and the other programs, which do not. All differences between the two groups of programs pertain to eigenray file I/O and usage.

5. Bellhop Failure

It was decided to test *DMOS's* ability to calculate reverberation on the BASE 04 setup by starting with a simple system and then approaching the actual conditions of the test by incrementally replacing the simplified conditions or parameters with the actual data. As each stage of complexity was added, the results were compared to those of the previous case and, initially, with a set of standard test results calculated using the normal mode theory.

The reverberation would be modelled for the conditions of a particular ping chosen by other researchers. These researchers were concurrently processing the recorded ping and their results were to be used as the baseline data set for the reverberation inversion to be performed later. The following table lists the parameters associated with the selected ping.

Table 3. Parameters Associated with the Selected Ping

Parameter	Value
Ping Time	2006-06-01 12:26:40.049
Transmitter/Receiver Depth	66 m
Transmitter/Receiver Position	36°18.317' N, 14°43.154' E
Transmitter/Receiver Speed	2.5 m/s
Bearing	018° True
Wind Speed	10 kt (estimated)
Sound Speed Profile	T0_00039

The first test run was performed with omnidirectional transmitter and receiver, a consistent 1500 m/s sound speed from the surface to the bottom, and a uniform bottom depth of 100 m. The results from using **Bellhop** should have been similar to normal mode results, and they were.

The actual BASE 04 conditions were then slowly reached by adding, in the following order:

- a two-element vertical transmitter,
- a 96-element horizontal receiver, and
- the actual bathymetry.

By this stage *DMOS* calculated reverberation results that were very reasonable. At this point there was only one more condition to add, the actual sound speed profile.

The times and locations of the various sound speed profiles recorded on the ping's date were examined in order to locate the one that was closest to the ping both geographically and temporally. The most suitable candidate was found to be the data from the recording T0_00039, which was recorded 200 m away from and 97 minutes after the time of the ping.

The following figure displays both the complete sound speed profile and the subset of points used in the processing as, respectively, the solid curve and the squares on it. The plot also indicates the depth at which the transmitter and receiver were located.

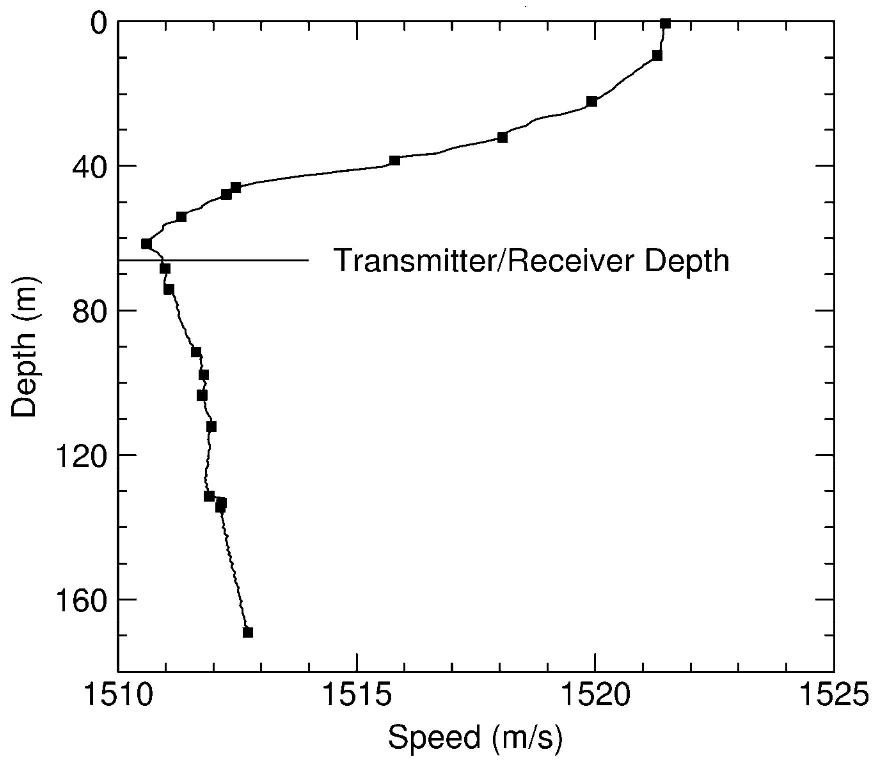

Figure 16. Sound Speed Profile T0_00039

Figure 16 indicates that the deepest water for which sound speed was recorded was almost 170 m. However the actual water depths in the test area were occasionally deeper than this. To fill in the depth gap, the sound speed was extrapolated to a maximum value of 400 m, deeper than the deepest water encountered in the test.

When *DMOS* was given the selected sound speed profile, the reverberation results went astray from those produced during the previous test, although they initially started out with similar values. Figure 17 presents plots of two reverberation time series: one from the test case using a sound speed of 1500 m/s at all depths, and one with the T0_00039 profile's sound speeds. All other parameters are identical and are those of the actual event.

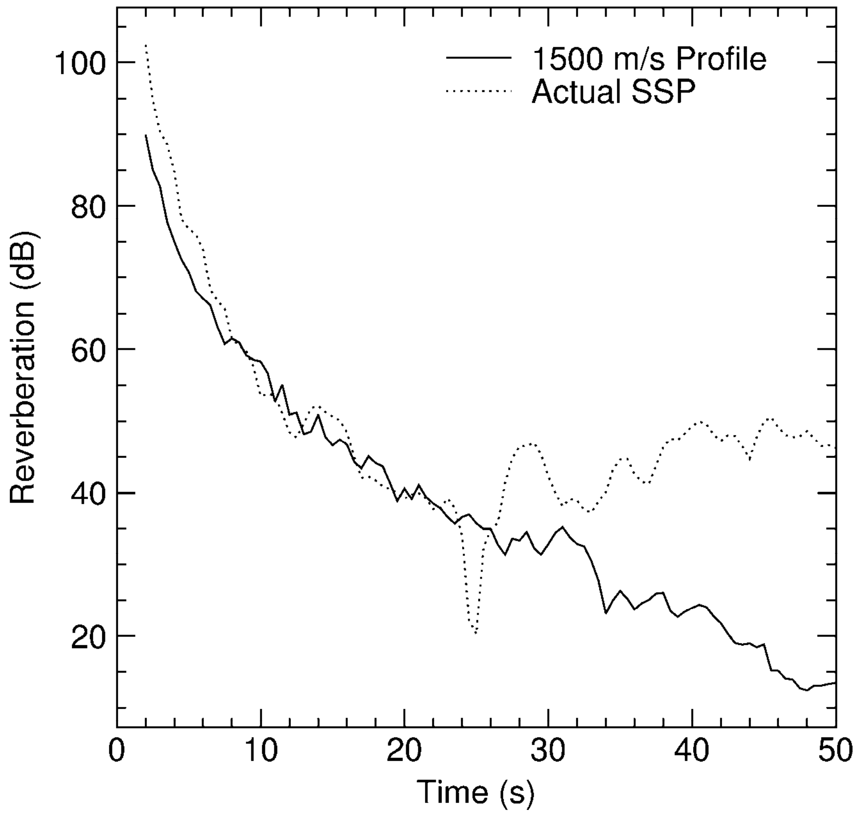

Figure 17. Reverberation Time Series Comparisons

It is apparent that the two sets of modelled reverberations match up fairly well up to about 22 seconds. At this point the 1500 m/s sound speed curve reverberations continue to decrease as would be expected, but the reverberations modelled from the actual sound speed profile dip sharply, and then rise towards the end of the time series.

The eigenray data files were examined and it was discovered that the amplitudes in the eigenray file produced by **Bellhop** did not attenuate appreciably, if at all, as time increased. As well, the counters indicating the number of top and bottom interactions remained at zero while the source and target angles varied between small positive and negative angles. This implied that low-incident angle eigenrays were being trapped by the fortuitous combination of sound speed profile and instrument depth, and so were oscillating vertically without touching either the surface or the bottom. It appears that **Bellhop** was unable to attenuate the rays' amplitudes properly, and so failed under these conditions.

As part of the investigation, and in an attempt to understand better what was happening, the data points of **Bellhop's** "arrivals files" for these two runs were examined and all data points with positive target (a.k.a. receiver) angles were placed on two scatter plots, as can be seen in the following figure.

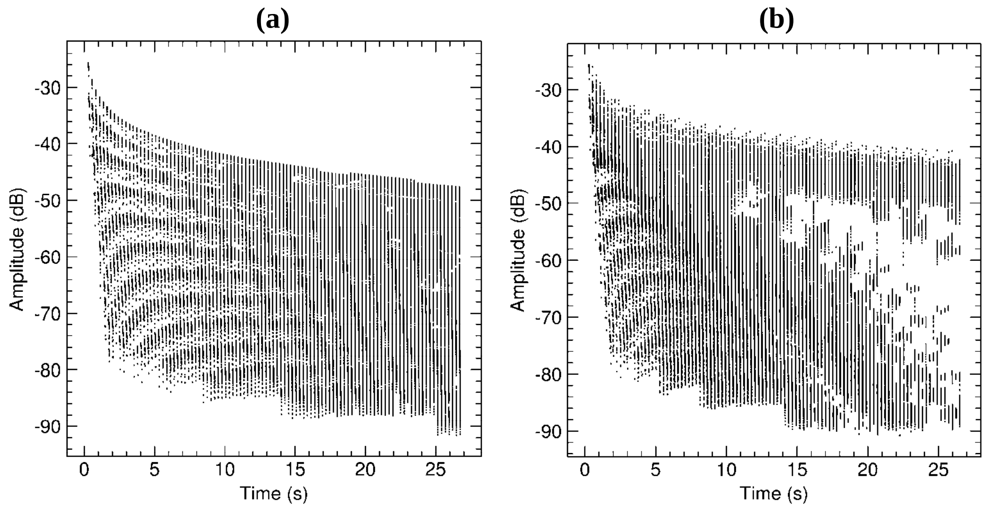

Figure 18. Amplitude v. Time Scatter Plots
(a) 1500 m/s Sound Speed Profile
(b) Sound Speed Profile T0_00039

Figure 18(a) contains 56,416 data points, which seem to be spread in a series of more-or-less horizontal bars. The apparent semi-constant time steps are due to the data being calculated at range increments of 400 m, which roughly translates to time steps of about 0.267 seconds.

Figure 18(b) presents the same type data from the case where sound speed profile T0_00039 was used. This resulted in the plotting of 73,710 data points, but in a pattern somewhat at odds with Figure 18(a). Instead of approximately horizontal bars, Figure 18(b) suggests that the bars drop downwards at a 45° angle on the plot. The only exception is the top bar, which roughly parallels the top of the Figure 18(a) data spread although it has a higher value.

Although the Figure 18 diagrams show differences, the fact that they are scatter plots and that data points can sit on top of one another obscures the actual density of the points. To sidestep this facet of the display the data points were binned into areas of 1 second in the X direction by 2 dB in the Y direction. This allowed a density map to be created for each set of data. Once the data were summed up, each bin was assigned one of 17 linearly scaled levels.

Figure 19 presents these density maps. The bin values of the two diagrams were scaled independently due to their having a different maximum number of bin counts; therefore they can only be compared in a relative way, which was the original intent.

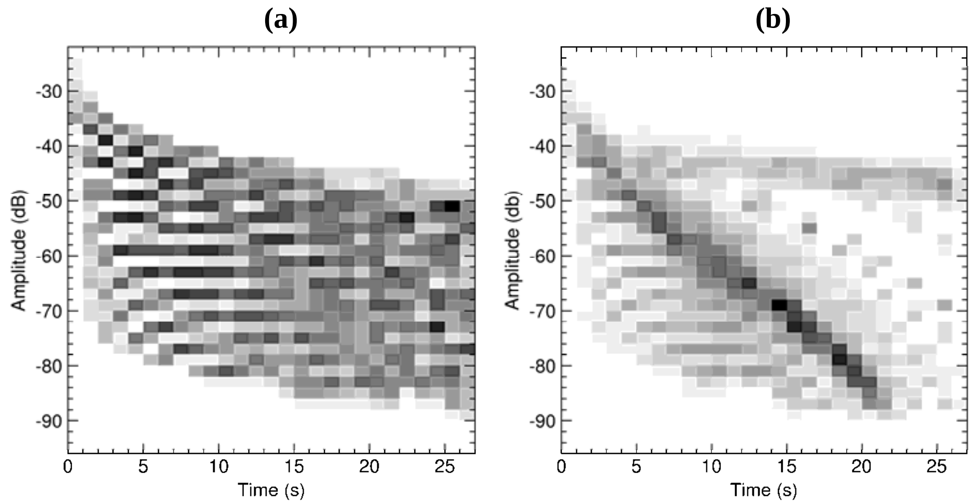

Figure 19. Amplitude v. Time Density Plots
(a) 1500 m/s Sound Speed Profile
(b) Sound Speed Profile T0_00039

The two diagrams of Figure 19 provide different detail than do those of Figure 18. Figure 19(a) shows that the data from the 1500 m/s sound speed profile are spread pretty much as suggested by Figure 18(a), with a number of horizontal bands merging after about 15 seconds.

Figure 19(b) displays something not apparent from Figure 18(b): The vast majority of the data points (and so the majority of the reverberation energy) is located on a linear feature that drops from high amplitude-low time to low amplitude-long time.

The meaning of this with respect to the differences in the two reverberation time series is not known to the author, but it does suggest that **Bellhop** may not be acting as expected.

Because the Figure 19 plots contain relative numbers of occurrences, the amount of energy in the various time bins can not be determined from the diagrams. Therefore one final look at the data from the two test cases was made. The same data used to produce Figures 18 and 19 were divided into bins 1 second wide and the amplitudes of the eigenray data points within those bins were summed. Then, because the range of values was so great, the sums were converted to dB. The results for both cases were plotted against time and are presented in Figure 20.

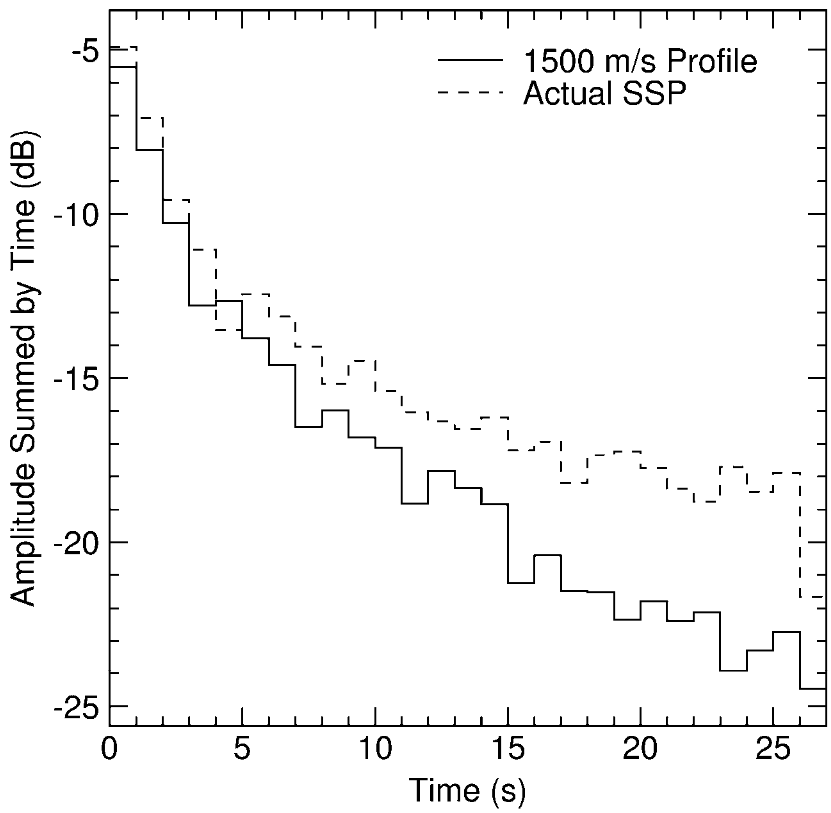

Figure 20. Amplitude Summed per second v. Time

It may be noted that only in the 4-5 second bin does the actual sound speed profile value drop below that of the constant 1500 m/s sound speed profile. Otherwise, both data sets start off roughly parallel, but the difference between the curves rapidly increases. By the end of the plot the curve based on the actual sound speed profile begins to level off although the constant 1500 m/s profile data continue to drop. The above plot clearly shows that **Bellhop** produces much more energy at increasing times for the actual sound speed profile than it does for the constant 1500 m/s profile. This increase in energy ultimately resulted in the differences in the two curves of Figure 17.

Whatever the problem with **Bellhop** is, it was apparent that the program could not be used with the current data set. Accordingly, another model was searched for that could provide eigenray data to *DMOS* for the calculation of reverberations.

Unfortunately, the amount of time required perform the earlier tasks of the contract and to make this discovery exhausted the time allowed for the contract. This prevented the comparison of modelled reverberation data with the results produced from an analysis of the recorded data.

Coincidentally, by the end of the contract time the analysis of the ping data analysis and the production of the reverberation time series, which was being performed by other personnel, had not yet been completed. Therefore even if **Bellhop** had been suitable for this analysis, the work could not have been done.

6. Conclusions and Suggestions

The work that led to this report resulted in several discoveries about *DMOS* and **Bellhop**. These discoveries, in turn, led to some conclusions about the programs used and suggestions for further investigation:

- The programs that calculate reverberation and transmission loss from eigenrays produced by various sources produce self-consistent results. This implies that these programs use the eigenrays in a consistent manner, and that the *DMOS* routines calculate results in a manner comparable with **GSM**.

- Differences between the various reverberation and transmission loss results can be traced back to differences in the eigenray data used as a basis for calculating these data sets. This means that **GSM** and **Bellhop** produce eigenrays differently.

- **Bellhop** is unable to calculate eigenrays correctly under certain conditions, when using the measured sound speed profile displayed in Figure 16 for example. This discovery was made fortuitously, and if the errors hadn't been so striking they might have been missed. The program should be examined to discover the reason for the errors and it should be fixed.

- **Bellhop** should be checked to ensure that it is calculating eigenrays properly. It isn't believed that the differences between **GMS's** and **Bellhop's** ways of calculating the eigenrays are due to any serious errors, but are more likely due to minor differences in technique or in initial assumptions and setup, numbers and angles of rays, for example.

  A first step in this check could have a tester running both **GSM** and **Bellhop** and making sure that every input parameter that the programs have in common have exactly the same values. And if it happens that a program has inputs not exactly analogous to inputs in the other program, care be taken to ensure that values for these parameters are chosen to make the overall input cases as similar as possible.

Overall, although this contract did not result in data analysis being performed, it did result in the expansion of **BREVER**, the testing and correction of some *DMOS* code, the validation of a number of portions of *DMOS*, and the discovery that under certain circumstances **Bellhop** could not be safely used.

Bibliography

[1] Calnan, C. (2004). *Reverberation Inversion Using SWAMI* (DRDC Atlantic CR 2004-113, December 2004)

[2] Calnan, C. (2005). *TIAPS "Through the Sensor Probing" Technique* (DRDC Atlantic CR 2005-033, March 2005)

[3] Calnan, C. (2006). *DMOS – Bellhop Extension* (DRDC Atlantic CR 2006-005, February 2006)

[4] Theriault, J.A. and Calnan, C. (2006). *DMOS User's Guide* (In Preparation).

[5] Calnan, C. (2006). *BREVER User's Guide, v. 1.0a* (In Preparation).

Initialisms and Acronyms

ASCII	American Standard Code for Information Interchange
ASSA	Adaptive Simulated Simplex Annealing
DASM	Directional Acoustic Sensor Module
DMOS	DRDC Atlantic Model Operating System
DRDC	Defence Research and Development Canada
GSM	Generic Sonar Model
HPA	Horizontal Projector Array
SWAMI	Shallow Water Active-sonar Modelling Initiative
TIAPS	Towed Integrated Active-Passive Sonar

Distribution List

Internal Distribution

2	DRDC Atlantic LIBRARY FILE COPIES
3	DRDC Atlantic LIBRARY (SPARES)
3	J. Theriault
1	S. Pecknold
1	J. Osler
1	D. Ellis
1	P. Hines
1	M. LeFrancois
1	B. Roger
1	G. Mellema

External Distribution

1	AUTHOR
1	D. McGammon McCammon Acoustical Consulting 475 Baseline Road Waterville NS B0P 1V0
1	LCdr W. Renauld, SSO METOC, MARLANT CFB Halifax
1	M. Prior, NATO Undersea Research Centre Anti-Submarine Warfare Department Viale San Bartolomeo 400 I-19138 La Spezia
1	DRDKIM 3

Total 20 copies

This page intentionally left blank.

DOCUMENT CONTROL DATA
(Security classification of the title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document, Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's document, or tasking agency, are entered in section 8.) Publishing: DRDC Atlantic Performing: xwave, 36 Solutions Drive, Halifax, NS Monitoring: Contracting:	2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.) UNCLASSIFIED

3. TITLE (The complete document title as indicated on the title page. Its classification is indicated by the appropriate abbreviation (S, C, R, or U) in parenthesis at the end of the title)

Reverberation Inversion Enhancements Using BASE 04 Data (U)

4. AUTHORS (First name, middle initial and last name. If military, show rank, e.g. Maj. John E. Doe.)

C. Calnan

5. DATE OF PUBLICATION (Month and year of publication of document.) October 2006	6a NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.) 52	6b. NO. OF REFS (Total cited in document.) 5

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical document, technical note or memorandum. If appropriate, enter the type of document, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Contract Report

8. SPONSORING ACTIVITY (The names of the department project office or laboratory sponsoring the research and development – include address.)

Sponsoring:

Tasking:

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant under which the document was written. Please specify whether project or grant.) 11cs	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.) W7707–05–2983
10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document) DRDC Atlantic CR 2006–046	10b. OTHER DOCUMENT NO(s). (Any other numbers under which may be assigned this document either by the originator or by the sponsor.) xwave contract 100997

11. DOCUMENT AVAILABILITY (Any limitations on the dissemination of the document, other than those imposed by security classification.)

Unlimited distribution

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11), However, when further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected.))

Unlimited announcement

UNCLASSIFIED

DOCUMENT CONTROL DATA
(Security classification of the title, body of abstract and indexing annotation must be entered when the overall document is classified)

13. ABSTRACT (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

(U) Previous contracts resulted in the development and use of the program BREVER, which performs reverberation inversion using the sonar analysis suite DMOS. A more recent contract allowed for the expansion of DMOS to incorporate the use of the ray trace program Bellhop as an alternative to the normal mode theory program PMODES.

The current contract called for the expansion of BREVER so that it is able to use the Bellhop–enabled version of DMOS. A User's Guide for the newly expanded version of BREVER was also to be written as a separate document. Both of these tasks were accomplished.

Initial testing of the BASE 04 configuration, performed as a prelude to analysis of that data, revealed a limitation of Bellhop previously unknown to both the author and the Scientific Authority. This limitation prevented using the expanded version of BREVER to perform reverberation inversion on the BASE 04 data, which was the last task on the current contract.

(U) Des contrats antérieurs ont permis de développer et d'utiliser le programme BREVER, qui exécute une inversion de réverbération à l'aide de la suite d'analyse sonar DMOS (Système d'exploitation de modèle de RDDC Atlantique). Un contrat plus récent a permis d'incorporer dans DMOS le programme de traçage de rayon Bellhop afin qu'il puisse être utilisé à la place du programme de théories du mode normal PMODES.

Le contrat actuel visait l'extension de BREVER afin qu'il soit capable d'utiliser la version Bellhop de DMOS. Un guide d'utilisateur de la nouvelle version étendue de BREVER a été rédigé sous forme de document distinct. Ces deux tâches ont été exécutées.

Les essais initiaux de la configuration des essais en mer BASE 04, effectués préalablement à l'analyse des données, a révélé une limitation de Bellhop que ni l'auteur ni l'autorité scientifique ne connaissaient. Cette limitation a empêché d'utiliser la version étendue de BREVER pour exécuter une inversion de réverbération sur les données BASE 04, qui était la dernière tâche du contrat actuel.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) Reverberation
Inversion
Underwater Acoustics
Models
Towed Array

UNCLASSIFIED

This page intentionally left blank.

Defence R&D Canada

Canada's leader in defence
and National Security
Science and Technology

R & D pour la défense Canada

Chef de file au Canada en matière
de science et de technologie pour
la défense et la sécurité nationale

DEFENCE DÉFENSE

www.drdc-rddc.gc.ca